

Commissioning Plans for the LHC Synchrotron-Light Monitors

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LARP CM13

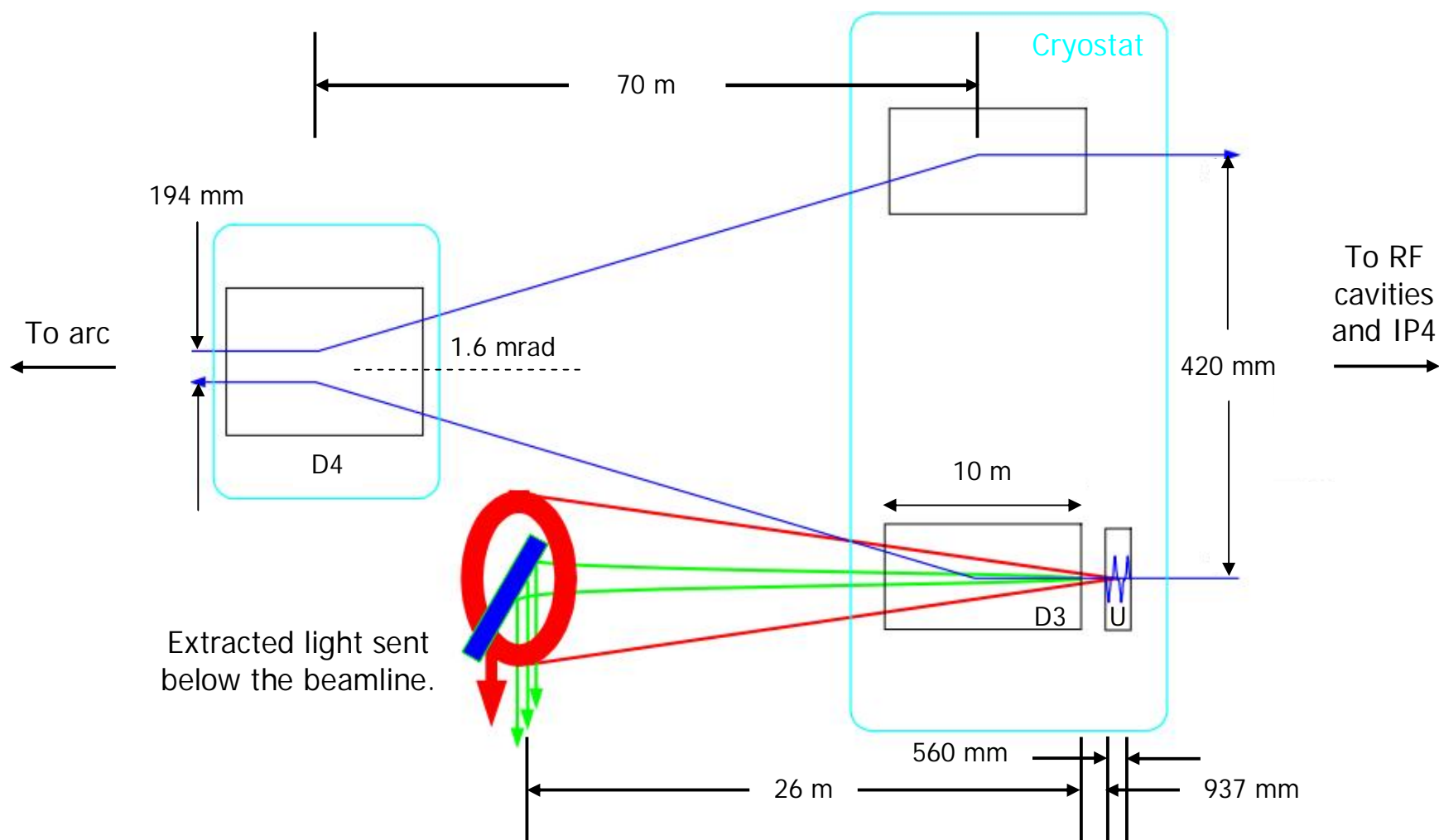
Port Jefferson, NY

2009-11-04

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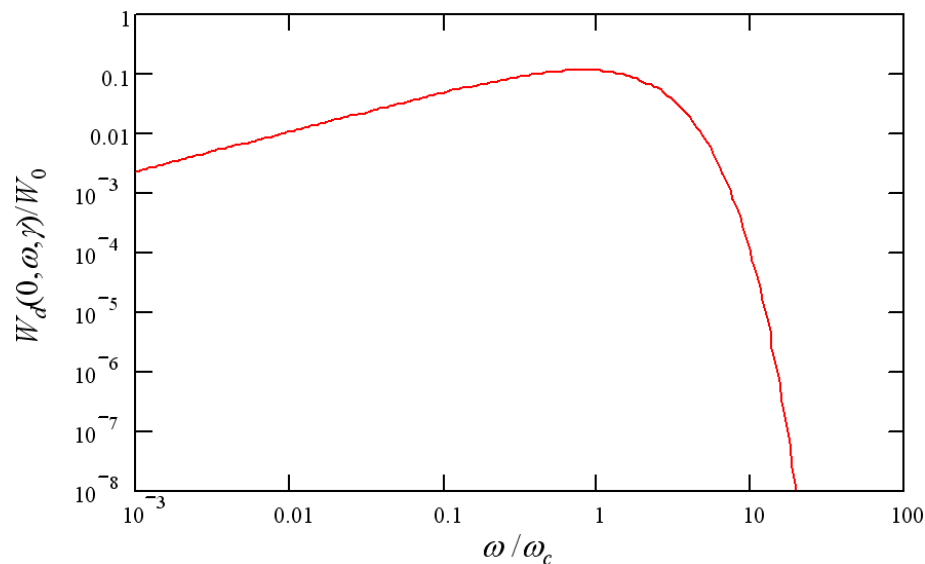
- Two applications:
 - BSRT: Imaging telescope, for transverse beam profiles
 - BSRA: Abort-gap monitor, to verify that the gap is empty
 - When the kicker fires, particles in the gap get a partial kick and might cause a quench.
- Two particle types:
 - Protons and lead ions
- Three light sources:
 - Undulator radiation at injection (450 GeV)
 - Dipole edge radiation at intermediate energy (2 to 3 TeV)
 - Central dipole radiation at collision energy (3.5 to 7 TeV)
 - Spectrum and focus change during ramp.

Layout: Emission and Extraction



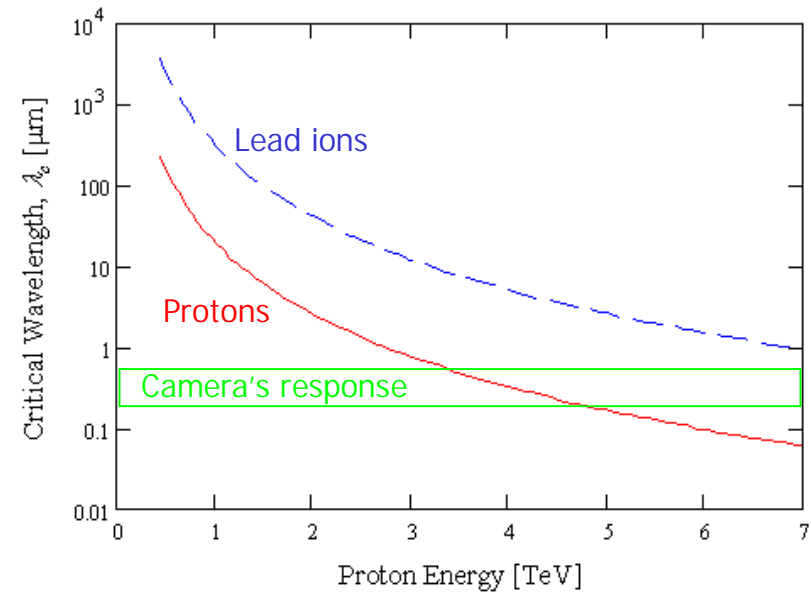
Spectrum of Central Dipole Radiation

Spectrum near Critical Frequency



- Normalized emission energy in dipole
- Frequency normalized to critical frequency

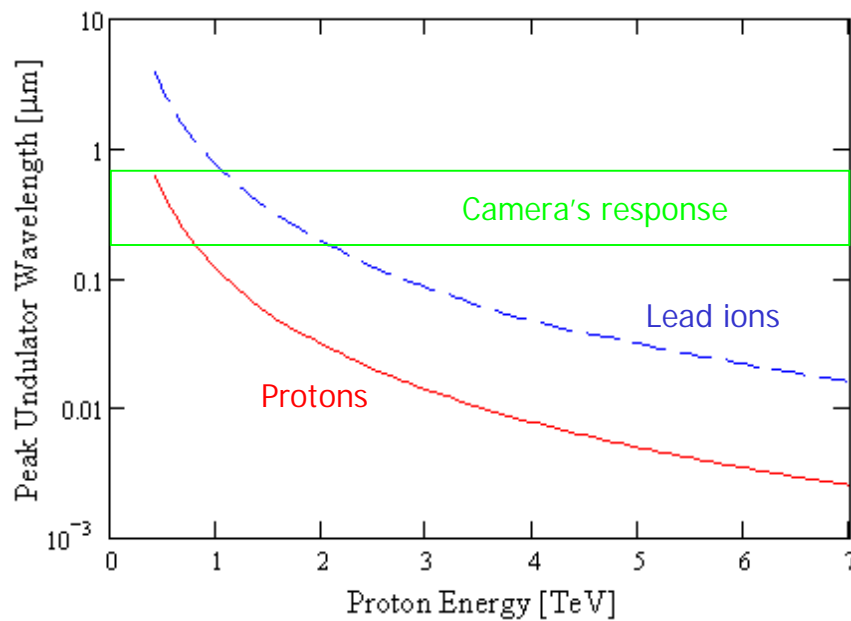
Critical Wavelength vs Beam Energy



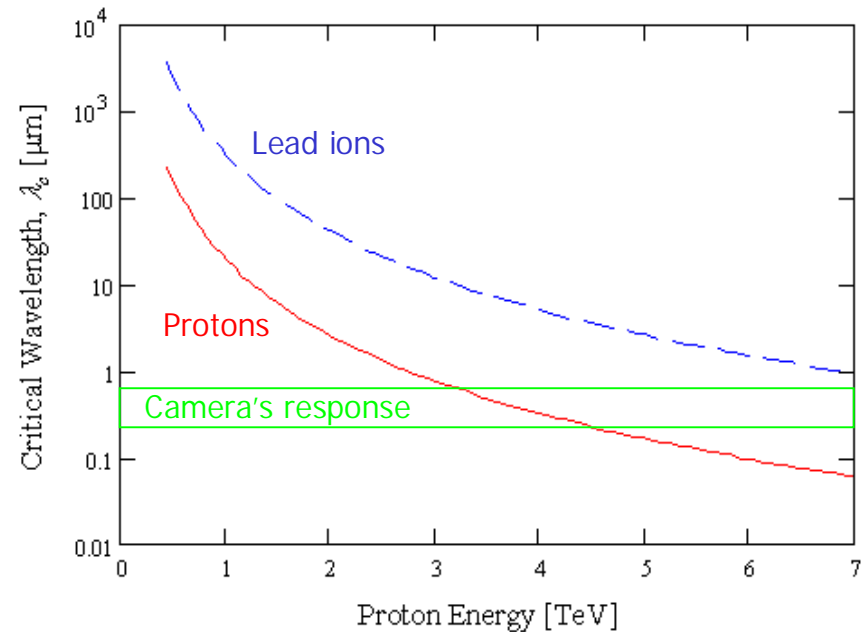
- Camera responds from near IR to near UV.
- Proton emission wavelength is too long at injection.
- Ion emission is too long below 3 TeV.
 - *i.e.*, dipole setting equivalent to 3-TeV protons

Undulator versus Dipole

Peak of Undulator Spectrum



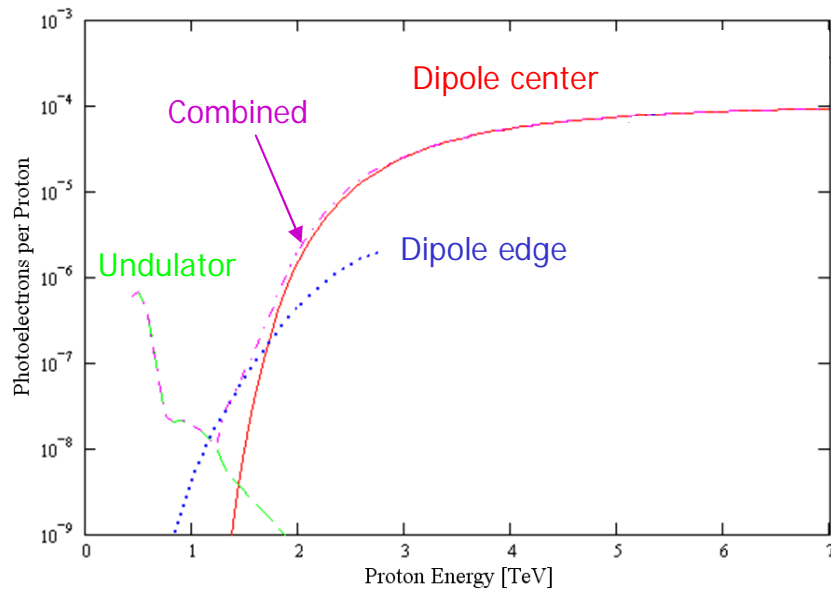
Critical Wavelength in Dipole



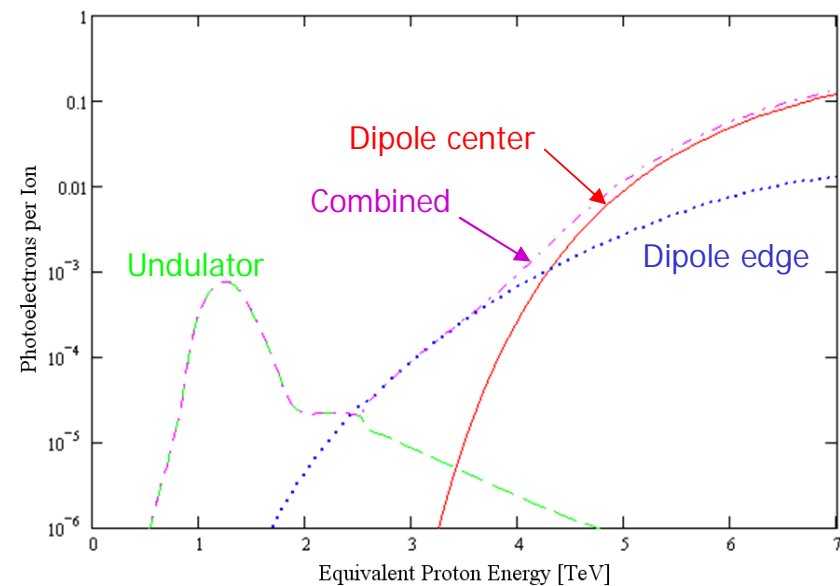
- Undulator provides response at proton injection.
- But response is still poor for ions at injection.

Photoelectrons per Particle at Camera

Protons



Lead Ions



- In the crossover region between undulator and dipole radiation:
 - Weak signal
 - Two comparable sources: poor focus over a narrow energy range
- Focus moves with energy: from undulator, to dipole edge, and then to dipole center.
- Dipole edge radiation is distinct from central radiation only for $\omega \gg \omega_c$

Particles per Bunch and per Fill

	Protons	Lead Ions
Particles in a pilot bunch	5×10^9	7×10^7
Particles in a nominal bunch	1.15×10^{11}	7×10^7
Bunches in early fills	1 to 43	1 to 62
Bunches in a full ring	2808	592

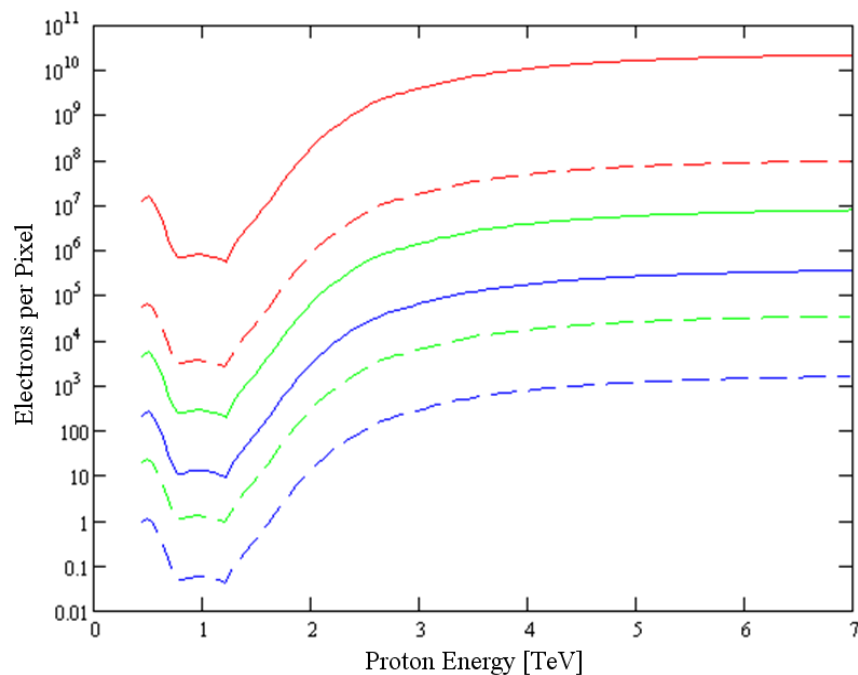
Beam Size and Critical Wavelength

Beam Energy		Beam Size at Source Point		Calculated Size on the Camera		Increase over Magnified Size ($M = 0.3$)	
(TeV)		$(\mu\text{m RMS})$		$(\mu\text{m RMS})$		$(\mu\text{m RMS})$	
		x	y	x	y	x	y
Protons	0.45	1302	1244	391	373	1.002	0.999
	3.5	473	447	146	139	1.030	1.035
	7	334	315	98.5	111	0.983	1.179
Ions	0.45	1304	1246	392	375	1.003	1.004
	3.5	473	447	144	135	1.013	1.006
	7	335	315	104	98.8	1.033	1.044

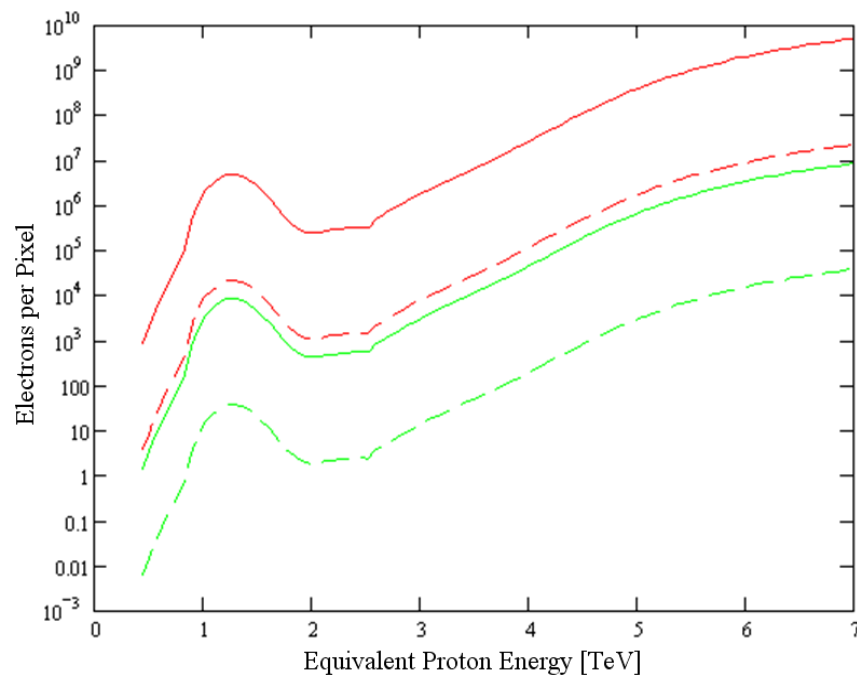
- Calculation includes geometric optics, depth of field, and diffraction.
- 400-nm wavelength is used, except at injection, where the undulator spectrum is shifted to the red and infrared.

Photoelectrons in the Peak Pixel

Protons



Lead Ions

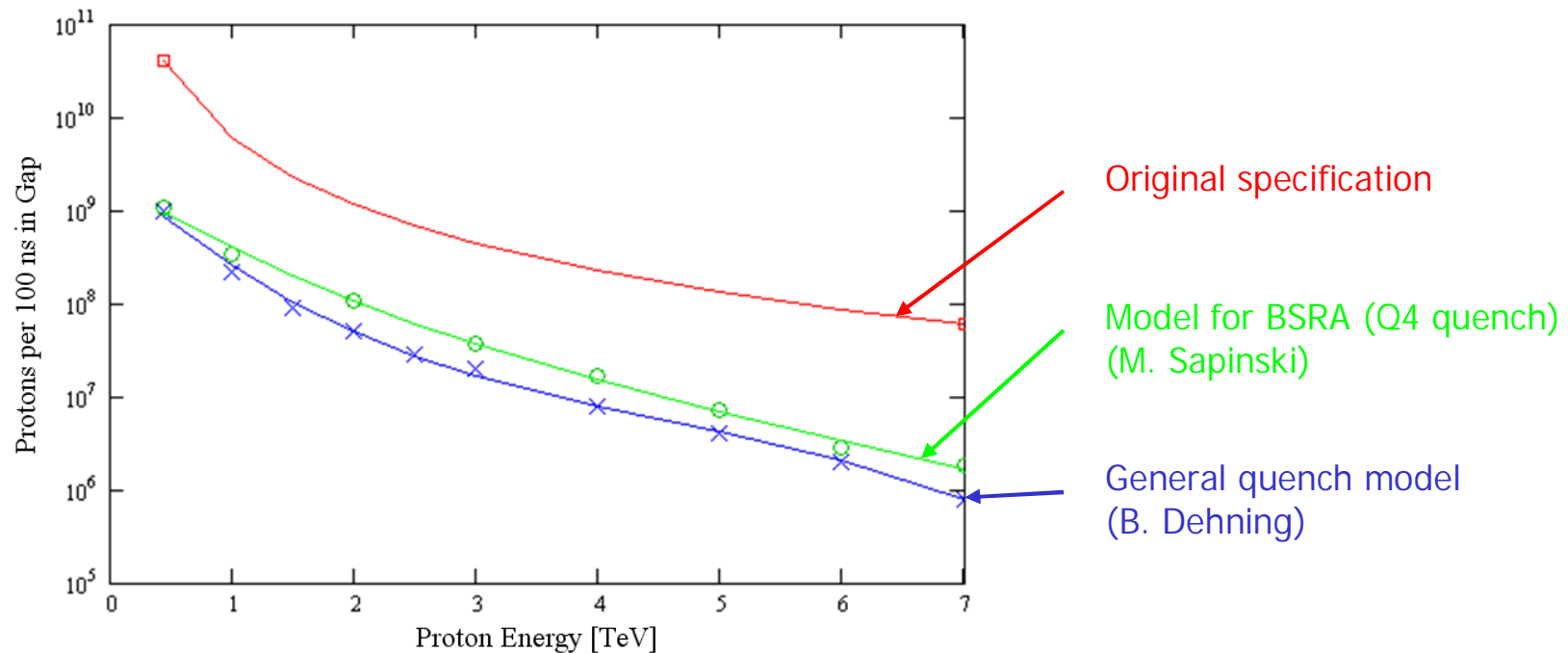


- Pilot bunch
- Single nominal bunch
- Full ring
- In one turn
- In 20 ms

- Emission increases with energy while beam size shrinks, giving a strong variation of the signal on the peak pixel.

- Gated photomultiplier gets ~15% of collected light.
 - PMT is gated off except during the 3- μ s abort gap:
 - High gain needed during gap.
 - No saturation when filled bunches pass by.
 - Pick off before all slits or filters for maximum light.
- Digitize the gap signal in 30 100-ns bins.
 - Sum over 100 ms and 1 s.
 - Longer integration needed when emission in PMT band is weak (protons at crossover and ions at injection).
 - Worst case signal-to-noise is 10 for 1-s integration at 10% of threshold.
- Requirement: Detect whether any bin has a population over 10% of the quench threshold.

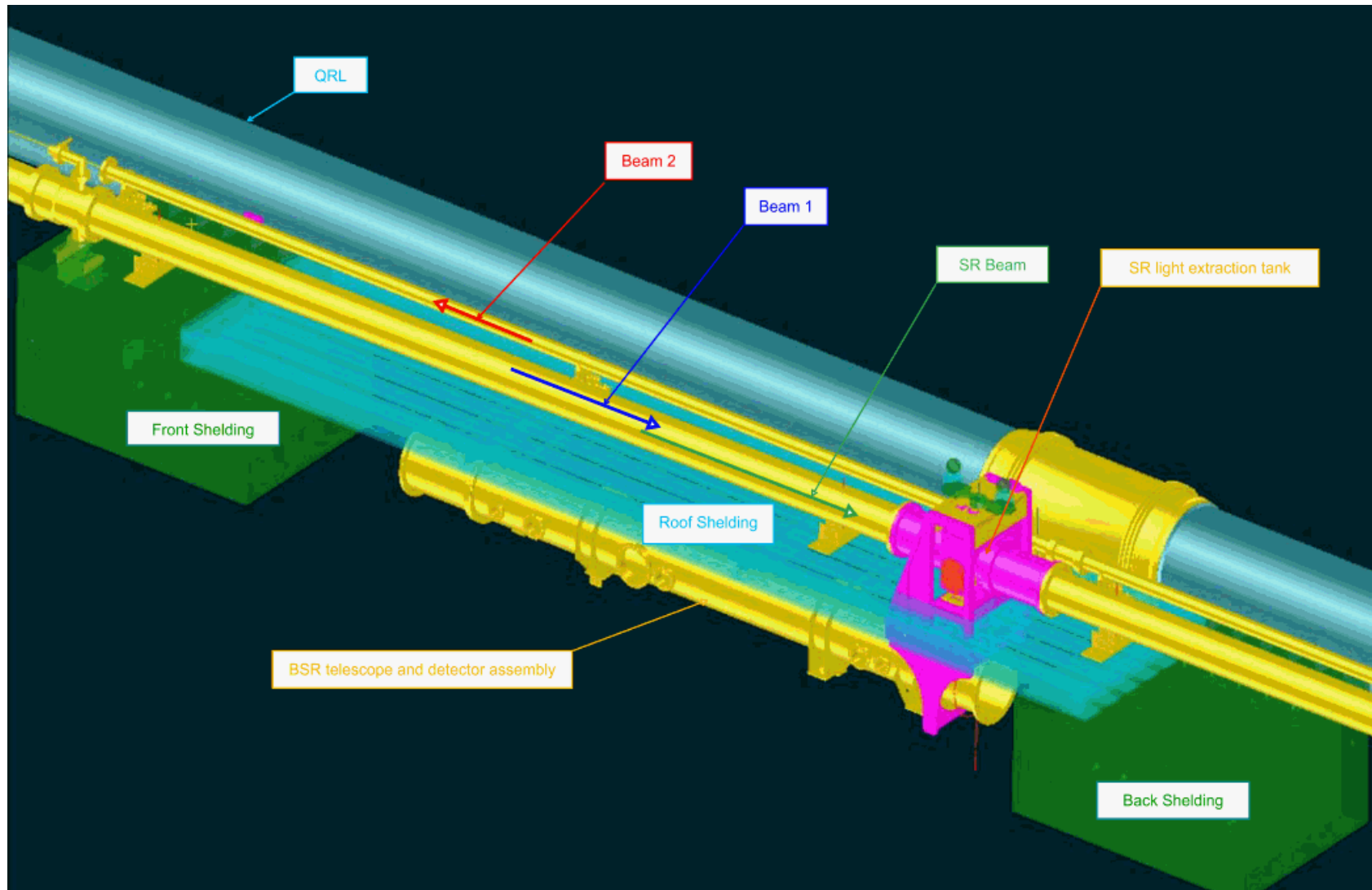
Protons/100ns at Quench Threshold



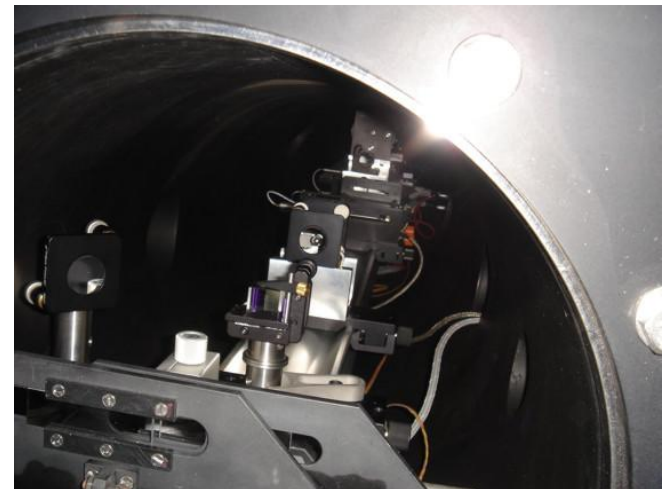
- Original threshold specification (given only at 0.45 and 7 TeV) was too generous.
- BLM group provided improved models. We used Sapinski's calculation.
- Ions fragment on beam screen, and deposit energy equivalent to Z protons at same point in ramp.

- Optical:
 - Add focus adjustment, since source moves during the ramp.
 - Add a calibration source.
- Mechanical:
 - The optics were housed in a tube (left over from LEP).
 - Replace with an optical table.
 - More space for optics. Better access for adjustment.
- Calculations:
 - Light level from protons and ions
 - Can the undulator stay on at high energy?
 - Minimize blurring from diffraction and depth of field.
 - Improve the optics for better imaging.
 - Monitoring abort gap even with weak light at injection.

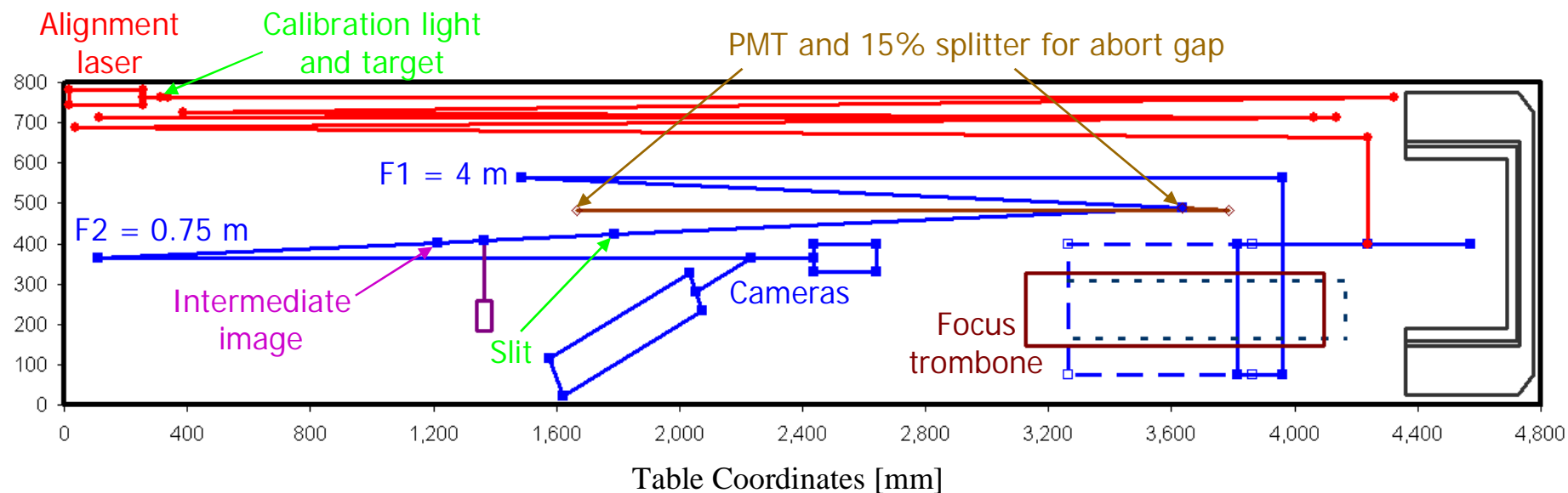
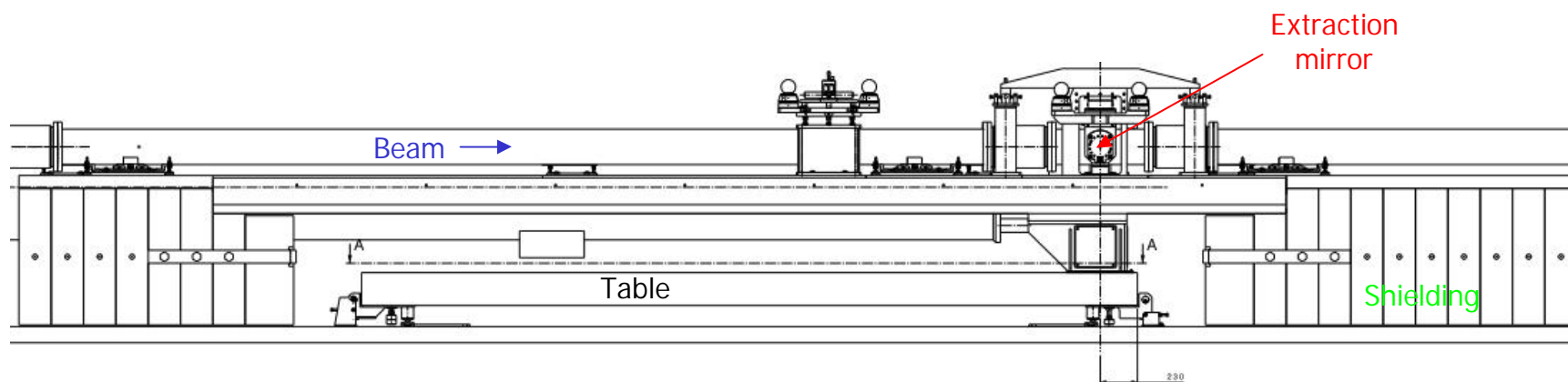
Original Optics Housed in a Tube



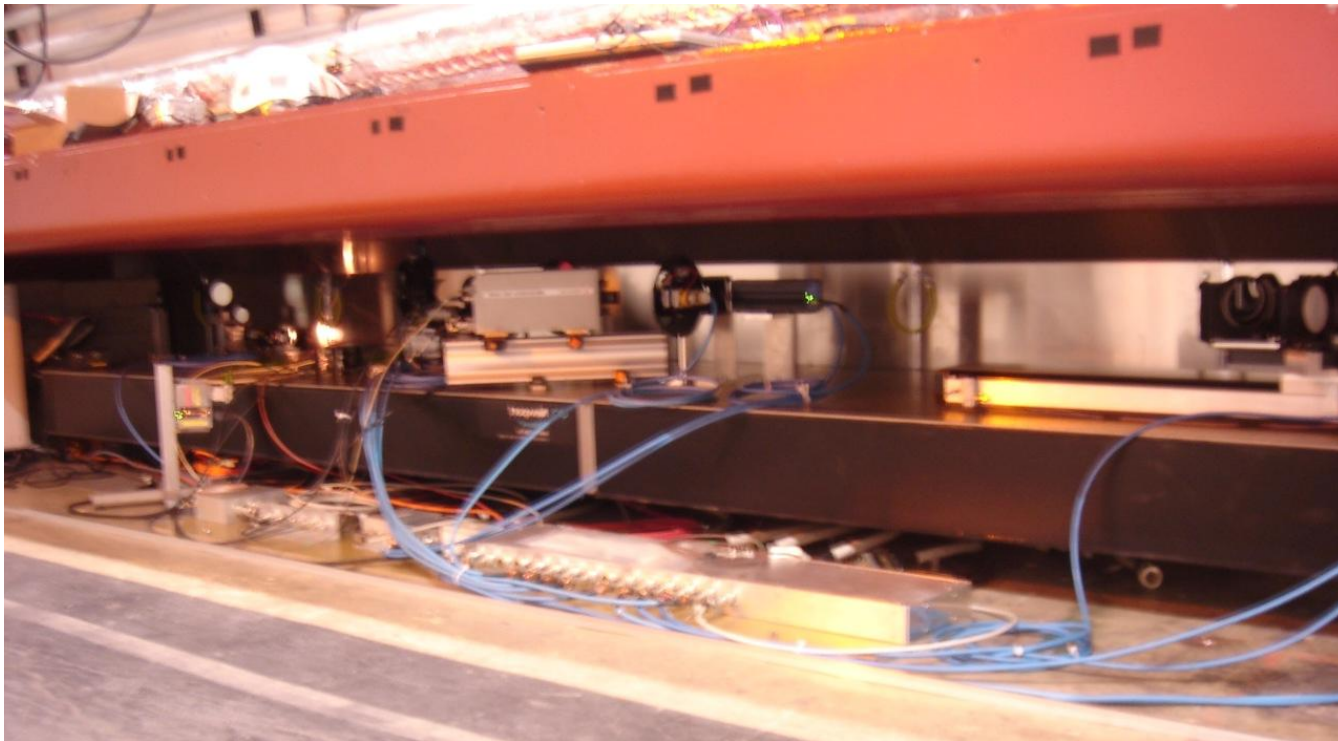
Poor Access with the Original Layout



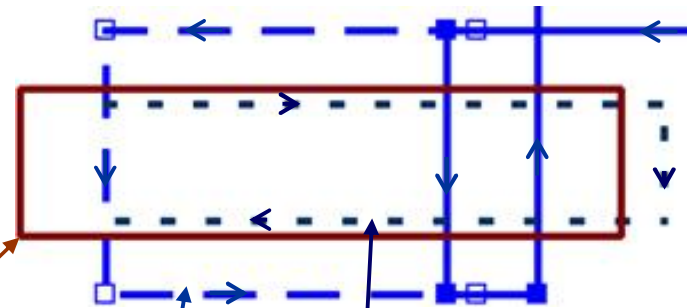
Layout with the New Optical Table



New Table Installed under Beamline

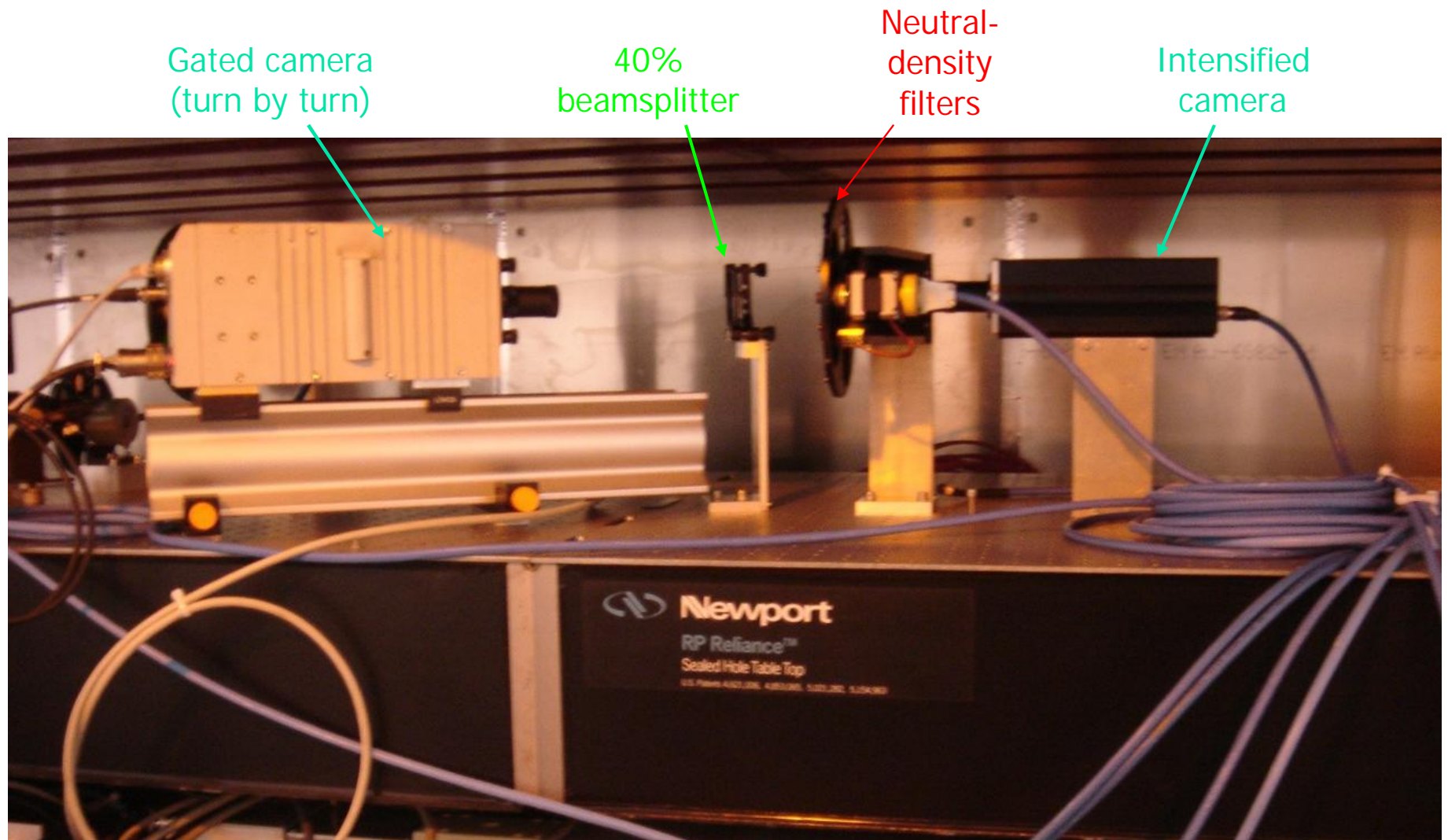


4-Pass Focus Trombone



- 600-mm translation stage
 - Outer trombone: 2 passes gives a 1200-mm range.
 - Inserting 2 mirrors converts trombone to 4 passes.
 - With a fixed extra path, the 4-pass mode spans 600 to 3000 mm.

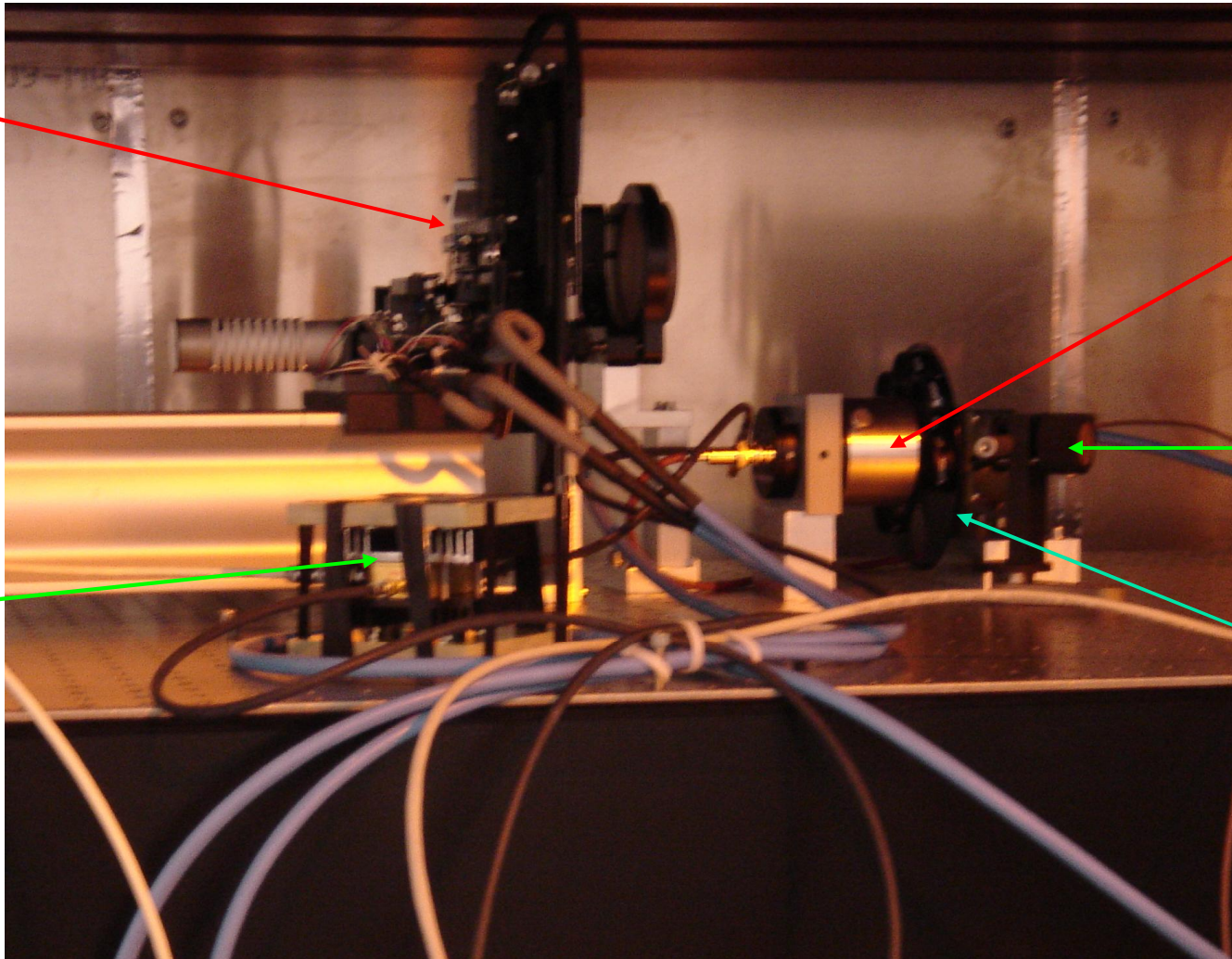
Intensified and Gated Cameras



Abort-Gap Monitor

Motorized
slit

Amplifier



PMT

Pulsed
LED

Neutral-
density
filters

- Undulator at full field
- Extraction mirror inserted
- Trombone at minimal delay (100 mm)
 - Source (undulator) is at longest distance
 - Inner trombone switched out
- No neutral-density or color filters inserted
- Maximum gain for intensified camera and PMT
- Maximum integration time for gated camera

- BSRA (Abort-Gap Monitor):
 - Set a wide gate that includes the pilot bunch.
 - Steer first two mirrors to find a signal on the PMT.
 - Avoid damaging PMT: Software alarm or feedback on high voltage
 - Insert filters as needed.
 - Shorten the gate. Verify timing using the pilot bunch.
 - Calibrate the signal level with the pilot bunch.
 - Reset the gate to span only the abort gap.
 - Remove filters for sensitivity to threshold gap population.

- BSRT Cameras:
 - Adjust steering as needed to get light on cameras.
 - Check that light remains on the PMT.
 - 10-mm diameter photocathode, placed at intermediate waist.
 - Adjust intensifier gain and gated-camera integration as needed.
 - Focus by scanning the trombone (expect ± 100 mm).
 - Determine steering needed to keep light on center of cameras.
 - Determine settings for:
 - Pilot bunch, 1 turn (gated camera) and 20 ms (intensified camera)
 - Nominal bunch, 1 turn and 20 ms
 - Multiple nominal bunches

- Don't change light path at first:
 - Measure beam displacements.
 - Measure intensity changes.
 - But keep the detectors from saturating.
- At end of ramp:
 - Resteer the light.
 - Adjust intensity.
 - Recalibrate the BSRA and cameras.
- Build up a calibration table for each energy step:
 - Steering
 - Intensity control

- Automatic (software) control depending on:
 - Particle type (proton/ions)
 - Beam charge
 - Bunch charge
 - Beam energy
- Adjustments:
 - BSRA settings:
 - Neutral-density filters and PMT high voltage
 - Motorized mirrors
 - Motorized slit on the focal plane of first focusing mirror
 - Camera settings:
 - Color and neutral-density filters
 - Gain and shutter for intensified camera
 - Integration time and framing speed for gated camera

- Stored beam expected in the next couple of weeks.
- I will go to CERN on Nov. 28 and stay until the holiday shutdown (Dec. 19).
- A proton photo album for CM14?